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SUBSIDENCE OF PEAT SOILS IN FLORIDA

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Introduction

In order to secure more definite information on the rate and amount of subsidence of Florida peat soils following drainage, Drainage Investigations of the Bureau of Public Roads of the U.S. Department of Agriculture, (now the Bureau of Agricultural Engineering) in 1915 began the location of profile lines over selected peat areas within the State. The work was begun by Chas. W. Okey, under the direction of S.H. McCrory, Chief of Drainage Investigations.

Following location of the lines, the first profiles were run in 1916, and these have been rerun at intervals in order to determine the rate and amount of soil subsidence. The years during which levels were run over all or a part of these lines are: 1916, 1917, 1918, 1921, 1933, and 1934.

Under a cooperative agreement between the Bureau of Agricultural Engineering, U.S. Department of Agriculture and the Everglades Experiment Station of the College of Agriculture, University of Florida, a further study of the factors causing the loss in depth of peat soils is now in progress. A series of eight plots, with the water table held at depths of 1 to 4 feet, and six well lines around Lake Okeechobee are equipped with automatic water stage recorders to assist in a more comprehensive study of subsidence. Such factors as depth of water table, slow oxidation, and compacting of soil are being given special consideration.

SOILS

Peat or muck areas selected for this study are located near Okeelanta in the upper Everglades, and Davie in the Lower Everglades. Other areas selected are near Fellsmere, Indian River City, Vero Beach, and the Everglades Experiment Station near Belle Glade, Florida.

The deposits in all these areas have been formed mainly through the partial decomposition of saw grass. They are thus principally composed of organic material, but contain variable amounts of inorganic matter according to the special conditions existent during the periods of their formation. Bulletin 190 of the University of Florida Agricultural Experiment Station describes these soils as follows: "The accumulation of plant residues under conditions of excessive moisture usually constitutes peat soils. Under such conditions the anaerobicity, or lack of air, largely prevents the decomposition of the freshly fallen material beyond a certain stage; hence the accumulation of such organic deposits from century to century."

The "Custard apple" or Okeechobee mucklands include about 20,000 acres lying in a zone of from a half to two and a half miles wide, along the east and south shores of Lake Okeechobee. The surface soil to a depth of six inches or more is composed of a heavy plastic material containing 40 to 50% of inorganic matter. This muck was largely formed by the sedimentary deposits of succulent water plants. The mineral matter is doubtless due largely to silt deposits from lake overflow.

Between the Okeechobee muck and the saw-grass peat soil is an intermediate type commonly called "elderberry" or "weed" land. The top soil is of a fibrous material more decomposed by weathering than the typical saw-grass soil. The subsoil, though principally composed of the brown fibrous layers of saw-grass peat contains layers of plastic, sedimentary muck. The area of "weed" or "elderberry" land is small.

By far the greater portion of the Everglades soil is composed of the typical saw-grass peat. This, until exposed to weathering, is of a brown fibrous nature. The partially decayed roots of the saw grass can readily be distinguished. The mineral content averages about 10 percent and the dry soil is much lighter than the Okeechobee muck. Thin layers of plastic muck are found to some extent in the saw-grass peat.

The term muck as commonly used is applied to all types of organic soils including "custard apple," the intermediate type, and the brown fibrous peat of saw grass origin, but in this report the term muck will be applied only to the predominately plastic types such as the "custard apple" soil and the term peat will be applied to the lighter fibrous types of primarily grass origin which include about 3,000,000 acres within the Everglades.

In the early plans for development of peat areas in Florida the rates and amounts of subsidence following drainage were not fully understood. An estimate made in 1912 by the Chief Engineer to the Internal Improvement Board, placed the shrinkage of peat soil in the Everglades at from 25 percent to 33-1/3 percent of the depth of the peat above the plane of the soil water after drainage. The Isham Randolph Commission in its plan of 1913 for drainage of the Everglades, estimated the subsidence after drainage at not over 8 inches. These estimates doubtless did not include the effects of burning which has been a factor in lowering the elevations of much of the peat soils of the State.

CAUSES OF SUBSIDENCE

Subsidence of peat soils is principally due to slow oxidation of drained peat resulting in a shrinkage of that portion of the soil above the water table. The oxidation of the organic matter in the soil is caused by bacterial action. The bacteria secure their food and energy by consuming organic matter. As a result of this process carbon dioxide is liberated. This action does not occur in a thoroughly saturated or perfectly dry soil. Some moisture is necessary and probably that moisture content which is most favorable to plant growth also provides the optimum condition for oxidation. When the soil voids are filled with water little or no oxidation occurs, therefore the effect of bacterial action is negligible in that portion of the peat below the permanent or minimum water table.

Large portions of the peat areas in the State have been reduced in elevation by fires, which once started are hard to put out. In some areas almost irreparable damage has been done. Not only do such fires result in loss of elevation, but they also cause an increase of lime or other alkalies in the top layer. It is then necessary to reduce the excessive alkalinity by special treatment with sulphur, manganese sulphate or other chemicals before good plant growth can be secured. Particularly in uncultivated soil, follow-

ing long dry spells, large cracks 3 inches to 6 inches wide and 2 feet or more in depth often occur. This is a most favorable condition for burning as the fires work down into the cracks and only heavy rains or flooding by pumping can then extinguish them. The surface is sometimes lowered as much as a foot in a single burning.

Cultivation has a tendency to compact the soil and produces some subsidence. Prior to cultivation the top portion of the peat is loose and spongy and will readily absorb water, but with plowing and disking the soil is compacted to some extent. The amount of compacting will decrease from the surface downward and probably is of little consequence below the permanent water table.

In the case of the subsidence lines here discussed, it is impossible to determine what portion of the total loss is due to each of the above mentioned causes, but it is certain that slow oxidation of drained peat is the principal cause of subsidence.

Some elevations of the water table were obtained when the lines were run but the average elevations and fluctuations are not known. The results show only the total losses in elevation from all causes.

The Upper Everglades at Okeelanta

The early drainage in the upper Everglades around Lake Okeechobee was entirely by gravity, but as subsidence continued it became increasingly necessary to resort to drainage by pumping. The construction of the first pumping plant was begun in 1925 at South Bay. The area served by pumps was gradually extended until nearly all the cultivated acreage is now in pumping districts.

A subsidence line is located near Okeelanta about 4 miles south of Lake Okeechobee. The line as shown in Figure 1 extends east from the North New River canal, a distance of 6,650 feet and is parallel to and 280 feet north of the Bolles canal. From Station 10 to Station 28 plus 50 there has never been any cultivation. From Station 28 plus 50 to the end, all but approximately 650 feet has been in cultivation at various times for from one to three years prior to 1922. Since that date there has been no cultivation.

Almost all the area covered has been burned over at least four times since 1921. The burnings in 1922, 1926, and 1932 were severe and that of 1932 was the worst experienced. The land is now covered with a heavy growth of pigweed and other weeds.

The soil is a brown fibrous peat of saw-grass formation, sometimes referred to as Okeelanta muck. It is underlaid with a limestone formation classed as "Caloosahatchee marl." The average dry weight of the top 3 feet of soil was 6.2 pounds per cubic foot in 1916, and 7.7 pounds in 1918. This soil was taken from a section of the line never in cultivation. This increase in weight is doubtless due to compacting caused by drainage.

The North New River canal was opened in 1912 but effective gravity drainage was not available along the entire line until the Bolles canal was dug in the summer of 1914. For a number of years subsequent to 1914 the average depth of water table was 3 to 4 feet below the ground surface; but as subsidence continued this depth decreased until in recent years the drainage has been very inadequate. An examination of the subsidence profile shows the section from station 0 to station 10 to be about 0.2 foot lower in 1933 than the average for the entire line. The difference is probably due to the fact that the soil along this section of the line has been cultivated much of the time in recent years while that along the remainder of the line has had little or no cultivation.

The average surface elevation along the line was approximately 20.3 feet prior to drainage. The average depth of peat was then 11.6 feet. Subsequent levels over the line showed average elevations and subsidence as shown in Table 1.

Table 1.- Subsidence along the Okeelanta Line

	Elapsed time	Average elevation	Depth of peat	Subsidence for period	
				Amount	Annual rate
	Months	Feet	Feet	Feet	Feet
August, 1914	0	20.30	11.60	----	----
May, 1916	21	18.50	9.80	1.80	1.03
April, 1918	23	17.80	9.10	0.70	0.36
June, 1921	38	17.15	8.45	0.65	0.21
February, 1933	140	15.50	6.80	1.65	0.14

The elevation for June, 1925, is not used in the above tabulation as levels that year were run over only about a third of the line and the average elevation may not be correct for the entire line. The date on which drainage became effective is only approximate. The total subsidence is 4.80 feet which is 41 percent of the original depth of peat. Figure 2 shows graphically the amounts and rates of subsidence for the Okeelanta line.

The photograph, Figure 3, was taken in June, 1932. It shows a bench mark on a 40 acre tract immediately south of the Bolles canal and east of the North New River canal. It is probably not over 1,000 feet south of the subsidence line. The bench mark is fastened to an iron pipe about 15 to 20 feet in length extending down to a solid foundation. This tract of land has been in cultivation for the past 10 years, and for a considerable part of the preceding 10 years. There has been little if any burning during the past 20 years. The subsidence is therefore due almost entirely to causes other than burning.

The top of the pipe is approximately the original elevation of the soil. The horizontal marks show the elevations at subsequent dates. These agree quite closely with the average profile elevations on the subsidence line. The total subsidence of the peat around this bench was approximately 4.4 feet in July, 1932. As the subsidence around the bench

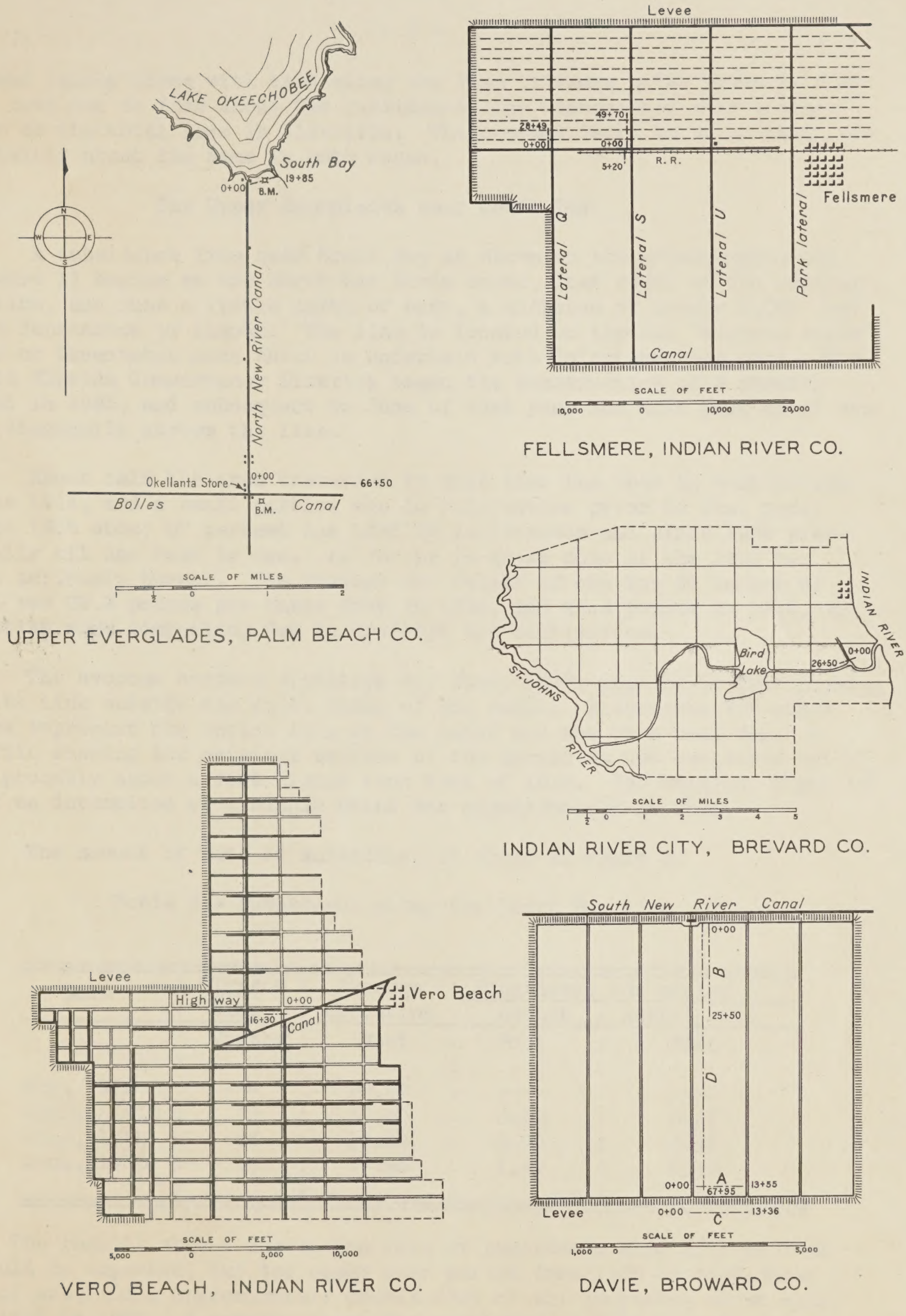


Fig. 1.-Location of subsidence lines on Florida drainage districts

agrees fairly close with that along the line it seems quite probable that the loss due to fire along the subsidence line represented only a minor part of the total loss in elevation. The average depth to water table was certainly about the same in both cases.

The Upper Everglades near South Bay

A subsidence line near South Bay as shown on the accompanying map (Figure 1) begins at the North New River canal, just south of the pumping station, and runs a little north of east, a distance of nearly 2,000 feet to a depression or lagoon. The line is located on typical "custard apple" land or Okeechobee muck which is underlaid with Caloosahatchee marl. The South Florida Conservancy District began the construction of a pumping plant in 1925, and subsequent to June of that year the main pump canal was dug diagonally across the line.

About half the area traversed by this line has been in cultivation since 1914, and a small portion was in cultivation prior to that year. Since 1916 about 87 percent has been in cultivation and since 1925 practically all has been in use. As far as is known none of the land has been seriously burned. The average dry weight of the top 20 inches of soil was 22.2 pounds per cubic foot in 1916, and 23.6 pounds in 1918, indicating some compacting due to drainage and cultivation.

The average surface elevation for June, 1933, applies to that portion of the line outside the waste banks of the canal. Elevations for other years represent the entire line as the canal had not then been dug. A profile showing the original surface of the ground is not available but it was probably about a foot higher than that of 1916. The original depth of muck as determined at a single point was approximately 14 feet.

The amount of rate of subsidence is shown in Table 2.

Table 2.- Subsidence along the South Bay Line

Date	Elapsed time	Average elevation	Subsidence for period: Amount	Subsidence for period: Annual rate
	Months	Feet	Feet	Feet
May, 1916	---	20.52	----	----
April, 1918	23	20.00	0.52	0.27
June, 1925	86	19.30	0.70	0.10
June, 1933	96	17.83	1.47	0.18

The results show a decreasing rate of subsidence from 1916 to 1925 as would be expected, but the eight year period from 1925 to 1933 shows a rate of subsidence approximately double that of the preceding seven years from 1918 to 1925. A pumping plant was completed in 1926 because gravity drainage had proved to be inadequate and as the profile line is close to

the pumps it is certain that the average water table after that time was much lower than previously. When the levels were run in June, 1925, the water table was about a foot below the surface. This comparison shows that the amount of subsidence depends to a large extent on the depth to water table.

The subsidence from 1916 to 1925 along that portion of the Okeelanta line run in 1925, and also around the bench mark south of the Bolles canal was 1.70 feet, whereas that along the South Bay line for the same period was 1.52 feet. This difference is doubtless due to the greater density of the custard apple muck. The dry weight of this muck due to greater mineral content was more than three times as great as that along the Okeelanta line. Less compacting would therefore result.

Fellsmere

The second largest peat area in the State is located near Fellsmere. The Fellsmere Drainage District was completed about January, 1915. Drainage is entirely by gravity.

As shown on the accompanying map (Figure 1), a subsidence line begins at a point on the railroad 219 feet west of Lateral S and runs north a distance of 5,000 feet to a point 235 feet west of this lateral. The soil is saw-grass peat underlaid with sand or marl. The land along this line first received effective drainage about the end of 1914. A levee extends along the west side of Lateral S, and the drainage outlet is to the west into Lateral Q. When the last levels were run in January, 1933, the water was very close to the surface along the entire line and the sub-lateral ditches were almost obliterated. There was a scattered growth of weeds.

There was very little cultivation along the line prior to 1917 but in that year 42 percent of the land was in crops. In 1918 the cultivated area was increased to 55 percent. Since 1918 only a very small portion of the land has been used for agricultural purposes and since 1925 all has been idle. The north 950 feet of the line has never been cultivated, yet the subsidence for this portion is practically the same as the average for the whole line, indicating that cultivation has been only a minor cause of subsidence.

The whole area was severely burned in the spring of 1935 and probably to some extent prior to that date. By what amount burning lowered the surface elevation is not known, but the subsidence curve would indicate that it was not a large factor. Certainly the lowering of the water table by drainage has been by far the principal cause of subsidence.

Table 3 shows the surface elevations, and subsidence along line S since drainage began.

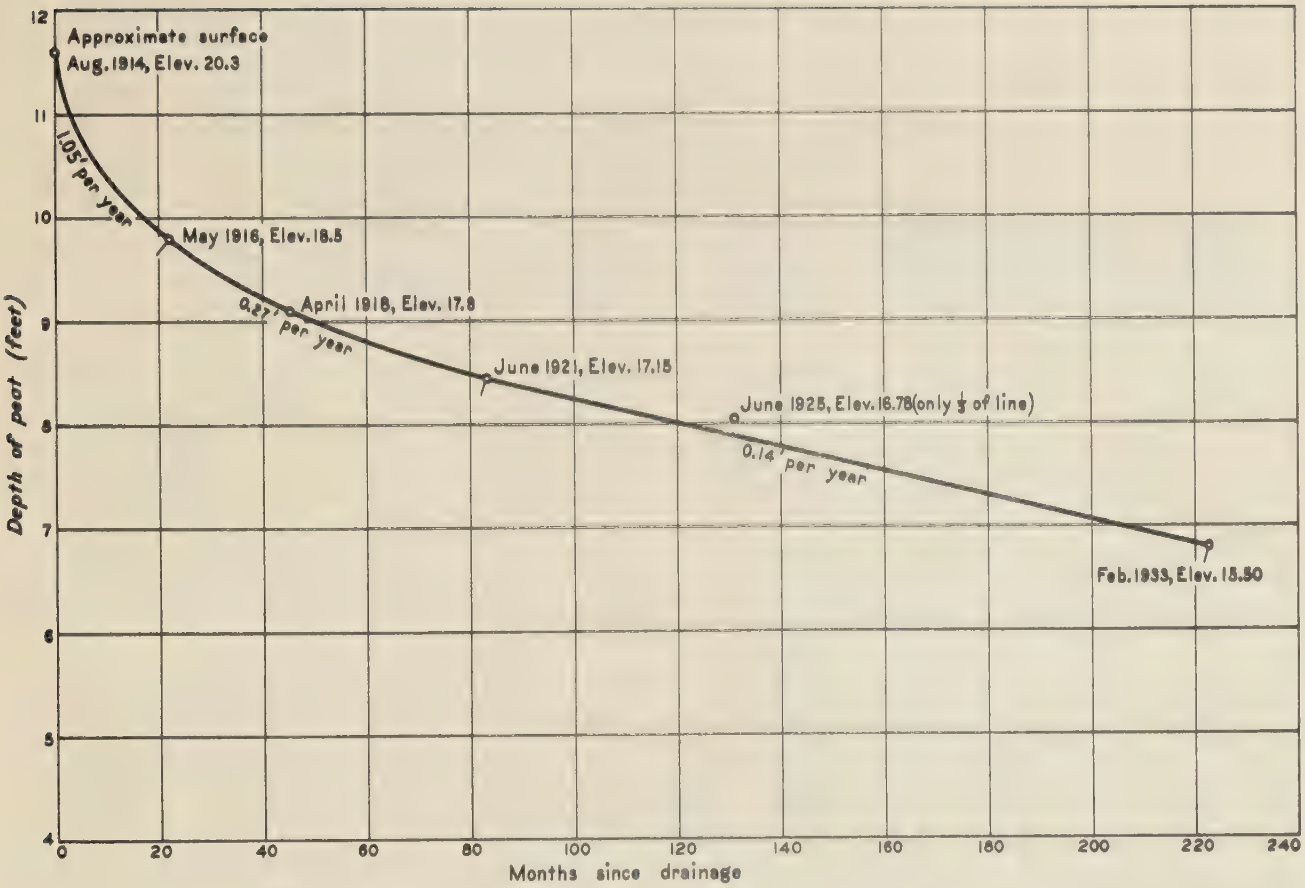


Fig. 2.-Okeelanta Muck Profile, Muck subsidence along Bolles Canal

Figure 3.- Government bench mark near Okeelanta. (year and elevation of surface are shown for several periods of subsidence)

Table 3.- Subsidence along Line S near Fellsmere

	Elapsed time	Average elevation	Depth of peat	Subsidence for period: Amount	Subsidence for period: Annual rate
	Months	Feet	Feet	Feet	Feet
January, 1915	0	22.65	7.25	0.00	----
February, 1916	13	21.53	6.13	1.12	1.03
June, 1918	28	20.70	5.30	0.83	0.36
May, 1921	35	19.94	4.54	0.76	0.26
June, 1925	49	19.13	3.73	0.81	0.20
January, 1933	91	18.18	2.78	0.95	0.13

The above data are shown graphically in Figure 4. This curve shows a consistent decrease in the rate of subsidence since drainage. The highest rate of subsidence was during the first year following drainage and averaged about a foot. During the last eight years the rate dropped to 0.13 foot per year. Probably the average water table during the last eight years was between 1.5 and 2.0 feet. The total subsidence since drainage is 4.47 feet. This is 61.7 percent of the original depth of peat.

It is believed that the conditions existing along this Fellsmere line and the Okeelanta line are rather similar. The soil along both lines has been cultivated very little, and in both cases is of grass origin. Both lines have been burned over, and both are approximately parallel to a large ditch; the Okeelanta line being 280 feet back from the ditch, and the Fellsmere line 227 feet. It is probable that the difference in elevation of the water tables was not great.

A comparison of Figures 2 and 4 show the subsidence curves for the two lines to be very similar. The dates when effective drainage was first established are not accurately known; those given are approximate. Therefore the rate of fall during the first year or two may be more or less than that shown. The date of effective drainage is taken to be that on which the ditch parallel to the line had been completed along the full length of the line and given a free outlet so as to provide drainage to the adjacent lands.

During the period from 1921 to 1933 the rate of subsidence was 0.14 foot per year for the Okeelanta, and 0.15 foot for the Fellsmere line. The total subsidence during a period of 223 months following drainage is approximately 4.80 feet for the one line and 4.55 feet for the other.

The original depth of peat along the Fellsmere line was 7.25 feet; that along the Okeelanta line was 11.6 feet, yet the total subsidence along these lines varies only 5 percent. It, therefore, seems highly probable that subsidence is limited to that portion of the peat above the permanent or minimum water table.

Subsidence line Q (North), is located approximately 227 feet west of Lateral Q in the west portion of the Fellsmere Drainage District (see figure 1). It begins at the railroad embankment and runs north a distance of 2,850 feet. The peat was burned over in 1921 and again in 1932. Only the south 700 feet of the line has ever been cultivated and that for only one or two seasons. The subsidence is due entirely to drainage and burning. In January, 1933, the levels were run to Station 14-00. The water at that time was a little below the ground surface.

This subsidence line was established in 1915. Subsequent profiles show a decided slope toward the ditch at the South end, due to the much better drainage of the land close to the ditch. The results again show that the deeper the water table the greater will be the subsidence. The amount and rate of subsidence for line Q (north) is shown in Table 4.

Table 4.- Subsidence along Line Q (north).

	Elapsed time	Average elevation	Depth of peat	Subsidence for Period	
				Amount	Annual rate
	Months	Feet	Feet	Feet	Feet
January, 1915	0	22.55	10.95	0.0	----
February, 1916	13	21.53	9.93	1.02	0.94
June, 1918	28	20.70	9.10	0.83	0.36
June, 1921	36	19.65	8.05	1.05	0.35
June, 1925	48	19.09	7.49	0.56	0.14
January, 1933	91	17.76	6.16	1.33	0.18

A comparison of the above table with Table 3 for line S, indicates that the amounts and rates of subsidence are quite similar for the two lines. The total subsidence along line Q was 4.79 and that along line S was 4.47. The original depth of muck was much greater in the one case than the other yet the total subsidence was not greatly different.

This comparison of lines Q and S makes it appear very probable that there is little or no subsidence in the peat below the permanent water table. The rate of subsidence along line Q from 1925 to 1933 was greater than that during the preceding 4 years. This is due probably to the heavy burning in the spring of 1932.

The original depth of peat along the Okeelanta line (see Table 1) was 11.6 feet, while that along line Q was approximately 11.0 feet. The total subsidence along the two lines was almost the same.

The Lower Everglades near Davie

One of the earliest projects for drainage and cultivation of the peat soil of the Everglades was located near Davie, at the lower end of the South New River canal. The development near Davie preceded that at Okeelanta by about two years.

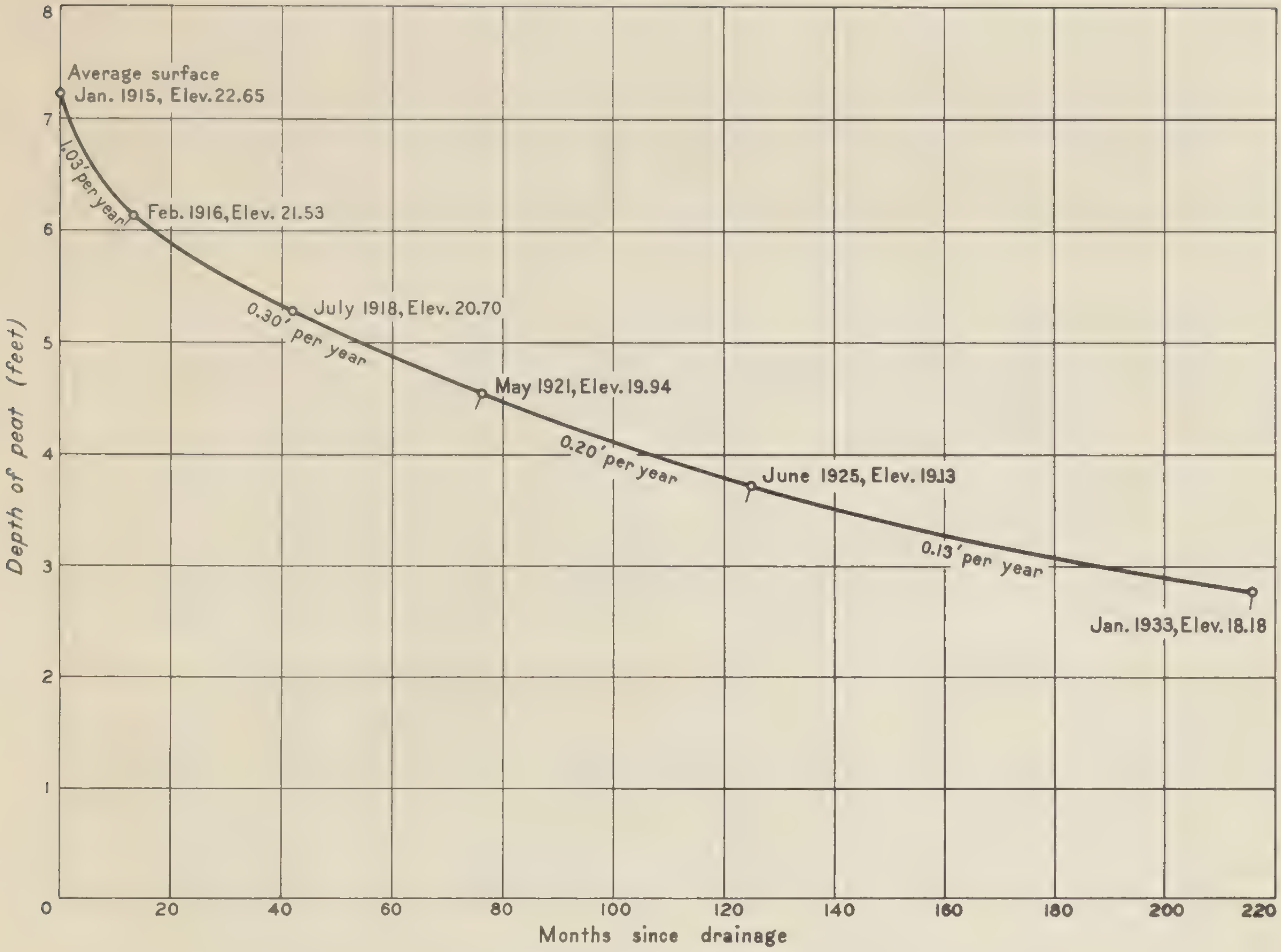


Fig.4.–Fellsmere Drainage District, Muck subsidence near Lateral S

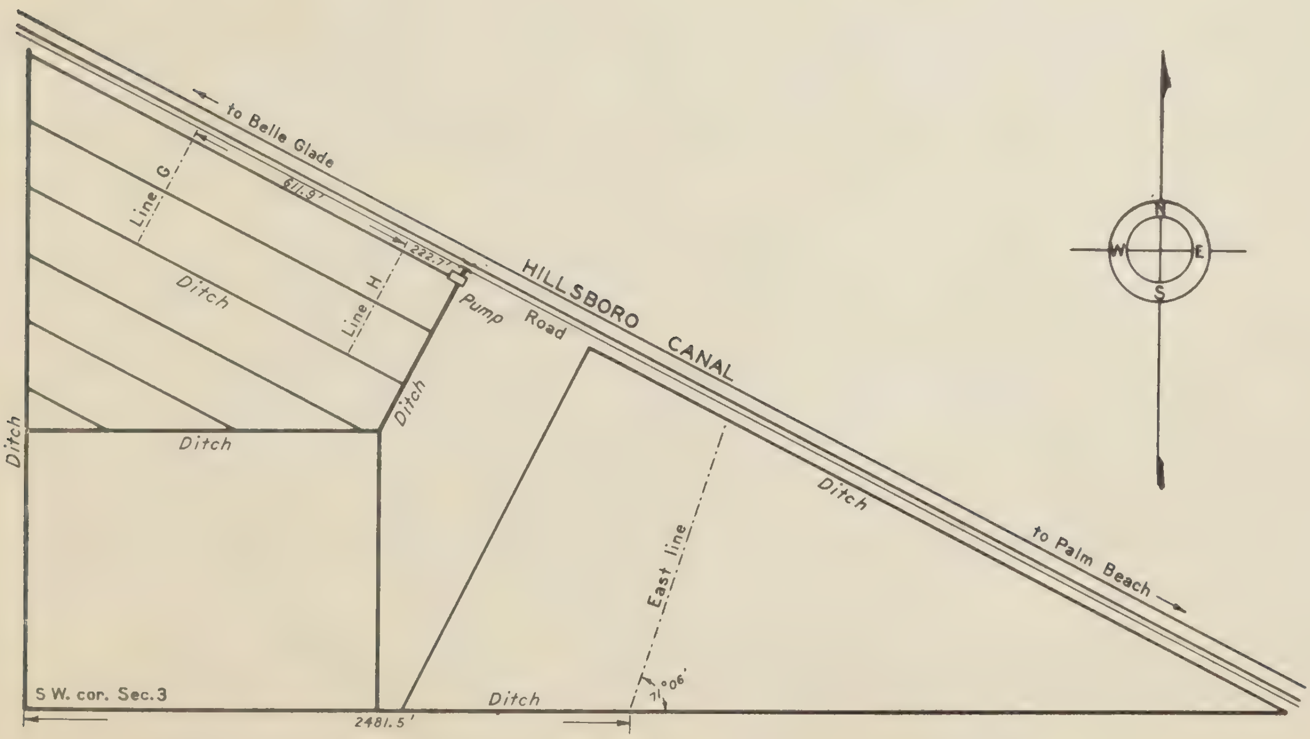
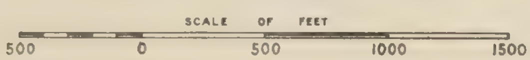


Fig. 5.–EVERGLADES EXPERIMENT STATION

BELLE GLADE, PALM BEACH CO., FLA.

Location of subsidence lines



The South Drainage District or Davie District was originally a pumped area, but about 20 years ago pumping was discontinued and the pumps finally dismantled. The land was later included in the Broward Drainage District which is a gravity drainage system. The ditches in the Davie area were enlarged subsequently to 1920. The area was first drained in 1913.

The subsidence lines near Davie are all within the old Davie district except line C which is 450 feet south of the levee. The locations of these lines are shown on the accompanying map (figure 1). The peat is principally composed of saw-grass deposits and is underlaid with sand or marl. The top soil is dark brown in color and fairly well decomposed. Levels showing the elevation of the surface soil before drainage are not available. Doubtless there had been considerable settlement prior to 1916. In recent years the water table probably has been below the bottom of the peat for a considerable portion of the time.

Subsidence line D begins at the South New River canal opposite the east wing of the Davie school building and runs south, approximately 7,000 feet to a large ditch along the inside of the levee. About 1,100 feet east of this line is a large ditch connecting directly with the South New River canal. One hundred and sixty-five feet west of line D is an old ditch, now almost filled up, which leads directly to the site of the old pumping plant.

Between station 14 and the south end, all but 900 feet of the line has been in cultivation for one or more seasons. Since 1921 only a small portion of line D has been in use. In 1933 less than a fourth of the line was in cultivation including the portion in orange groves. About 1,000 feet is now covered by a producing orange grove. The subsidence within the grove appears to be less than that on the portion where truck crops had been raised. This may be partly due to less intensive cultivation but is more probably due to the shallower depth of soil along that part of the line.

From Station 0 to Station 14, line D is located either on the school house yard or in an old abandoned orange grove. The subsidence along this portion is abnormally small due to special conditions. The following statements apply from station 14 to the south end of the line. The average surface elevation was 5.45 feet in 1916; 5.25 feet in 1918; 4.75 feet in 1921; 4.30 feet in 1925; and 3.55 feet in 1933. The average elevation of the underlying sand is 1.70 feet and that of the water in the surrounding ditches was 0.80 foot when the 1933 levels were run. These figures show an average depth of peat in 1916 of 3.75 feet and a total subsidence since that date of 1.90 feet or 51 percent of the depth.

From 1925 to 1933 the average subsidence was 0.75 foot. Should this rate of loss continue during the next 8 years, the average depth of peat will be less than a foot. As the water table during dry periods is often below the bottom of the deposit thus expediting oxidation and shrinkage it is probable that the peat will entirely disappear in a comparatively short time.

Line B begins at the South New River canal and runs south a distance of 2,550 feet. It is parallel to and 180 feet east of line D. The north 1,400 feet of line has been either cultivated or in orange groves since 1914 or 1915. In 1921 this section was all in a grove. In 1933 this grove was evidently abandoned and of little value.

Most of the south 1,150 feet of the line has been in cultivation, more or less, from 1913 to 1921. In 1921 there was no cultivation but in 1925 all was in use. In 1933 only the south 350 feet was in cultivation; the remainder was in weeds and probably had been idle for several years.

The northern section, through the old orange grove, showed more subsidence from 1916 to 1921 than during the longer period, from 1921 to 1933, while the southern section showed a greater amount during the longer period. This difference is due probably to the greater original depth of peat in the southern section. Had the minimum water table been above the bottom of the peat the subsidence would doubtless have been approximately the same even though there was a difference in depth. The greater depth of the south part would require more subsidence than the more shallow depth of the north portion before an equal density of soil was reached for the two sections.

In 1916 the average peat depth was 2.70 feet on the northern and 4.00 feet on the southern section. The amount of subsidence from 1916 to 1933 was 1.35 feet on the northern and 2.10 feet on the southern section. Both sections of the line had a subsidence of approximately 50 percent for the period.

Line A is located approximately 400 feet north of the south levee of the old Davie Drainage District, and crosses the lower end of line D. Along the inner toe of the levee is a large drainage ditch. The old ditch at the west end of this line is now of little value. At the east end is a large ditch connecting directly with the South New River canal. The land along the line has never been cultivated and is now being used as a pasture. The area was burned over prior to 1921. The water table in February 1933 was below the bottom of the peat. The depth of soil in 1916 was 4.20 feet, and the average subsidence from 1916 to 1933 was 1.85 feet or 44 percent of the depth.

Line C is located 450 feet south of the levee of the Davie District. The land has never been cultivated and is practically undrained, except for a small ditch of little value near Station 8+50. The line was burned over prior to 1921. The depth of peat in 1916 was 3.50 feet. The subsidence from 1916 to 1933 was 2.10 feet or 61 percent of the depth. Although in 1916 the surface on line C was about 0.30 foot higher than that on line A, the two were at approximately the same elevation in 1934. The line outside the levee showed the greater subsidence. This is due probably to the greater amount of burning along the outside line.

Table 5 shows the comparative subsidence of lines in the Davie area.

Table 5.- Subsidence along the Davie lines

Line	Station to Station	Depth of Peat in 1916	Subsidence 1916 to 1933	
		Feet	Feet	Percent
D	14+00 to 69+50	3.75	1.90	51
D	14+00 to 35+00	4.30	2.15	50
D	35+00 to 55+00	3.75	2.00	53
D	55+00 to 69+00	3.50	1.75	50
B	0 to 14+00	2.70	1.35	50
B	14+00 to 25+50	4.00	2.10	53
A	0 to 13+00	4.20	1.86	44
C	0 to 13+50	3.50	2.10	61

The above figures indicate that the subsidence from 1916 to 1933 on all four of the Davie lines has been approximately one-half the depth of peat. At least during recent years the water table has been below the bottom of the peat on these lines much of the time. Under such conditions it appears that the amount of subsidence is a rather definite percent of the depth of deposit. Where the water table is always above the bottom of the peat the subsidence would not be a definite proportion of the depth, as is shown on the lines near Okeelanta and Fellsmere. On such lines it is probable that the subsidence would be a definite proportion of the depth to the average water table.

Indian River City

As shown on the accompanying map (fig. 1), the subsidence line near Indian River City is located across a long narrow peat deposit about a mile west of Indian River. A large ditch, completed in 1914, cuts through the rims of the depression containing the deposit, and connects Bird Lake with Indian River. The line is located approximately parallel to and about 300 feet above this ditch, which has held the water table very low. The land has never been cultivated. The soil is primarily of saw-grass origin.

Levels were run over the line in 1916, 1917, and 1918. After 1918 no levels were run until May 1934. During this period the peat has been almost destroyed by fire. From Station 3+50 to Station 12 the surface is very irregular and is broken with large cracks 6 to 10 inches wide and 2 feet or more in depth. These cracks have evidently been enlarged by burning. Beyond Station 12 the burning has left the surface more even. From about station 20 to the end, the peat has been completely destroyed, and the underlying sand reduced to a lower elevation by erosion. The most severe burning occurred eight or nine years ago.

The average surface elevation between station 2 and station 25 was approximately 20.75 feet prior to drainage. In 1916, 1917, and 1918, the average elevations were 18.80, 18.10, and 17.70 respectively and in May 1934, the average elevation was 13.45. The original depth of peat was 8.65 feet. This subsidence line shows the possibility of the almost complete destruction of a deep peat deposit by fire when the water table is lowered to an excessive extent.

Vero Beach

The subsidence line near Vero Beach, as shown on accompanying map (fig. 1), is located on State Highway No. 30. It is approximately 230 feet south of the highway on soil that was once a saw-grass peat containing considerable sand. The first 100 feet of the line east of the road passes over a garden and lawn; the remainder of the line now runs through a citrus grove. The land has been in cultivation the greater part of the time since drainage.

Prior to drainage in June 1914, the deposit was 1.75 feet deep and was underlain with sand mixed with a small amount of peat. When the levels were run in 1933, the soil appeared to be almost entirely sand with a very little peat remaining. There is little difference in the profile of 1925 and that of 1933.

This line shows an almost complete loss of the deposit due to drainage, slow oxidation, and cultivation.

Everglades Experiment Station

The Everglades Experiment Station is located about two and a half miles southeast of Belle Glade on the south side of the Hillsboro Canal, as shown on the accompanying map (fig. 5). In November 1927, profile levels were run along three lines of wells indicated as line "G", line "H", and "East Line." On December 31, 1934, levels were again run over these lines to determine the subsidence over a period of approximately seven years.

These lines were originally established for the purpose of keeping a record of water table fluctuations and as a result of these records the average water table during the past seven years has been approximately determined. The soil is of typical saw-grass origin. The depth to rock is now about 6 feet. There has been no burning since the station was established in 1923.

These lines are added in order to better determine the effect of cultivation on the rate of subsidence. Conditions relative to burning, water table, and cultivation are more accurately known here than those for any other areas previously mentioned. The water table along the three lines has averaged approximately 1.8 feet below the surface. The water is held at a fairly uniform stage by means of a pump.

Lines "G" and "H" have been in almost continuous cultivation for the past ten years. The crops grown have been mainly truck. The land along the "East Line", has never been in crops, but has been plowed for the past two years. Thus it is seen that lines G and H have been in cultivation during the seven year period considered, and that the "East Line" was not even plowed for the first five years of the period.

EFFECT OF CULTIVATION

If cultivation is a decided factor in causing subsidence the comparison of these lines should so indicate. The results show a subsidence of 0.79 foot along ling G; 0.87 foot along line H; and 0.78 foot along the "East Line". In annual rates the results are 0.11 foot for line G; 0.12 foot for line H; and 0.11 foot for the "East Line." The average annual rate of subsidence along the cultivated lines was 0.12 foot while that along the line which was plowed for only two years was 0.11 foot. It thus appears that cultivation has had only a small effect on the rate of subsidence.

The record of cultivation, water table, and burning, along other lines considered in this report, is not sufficiently definite to permit accurate deductions as to the effect of cultivation. In the discussion of line 8 near Fellsmere it was stated that the subsidence along the north 950 feet of the line, which had never been cultivated, was practically the same as that along the south 4,050 feet, most of which had been cultivated from one to three years but the relative amount of burning is not known.

In the discussion of the Okeelanta line, it was noted that the total subsidence of the west 1,000 feet was about 0.2 foot more than the average for the entire line, the difference being probably due to cultivation. It was also noticed that the subsidence around the old Government bench mark near Okeelanta did not vary much from that along the subsidence line. The land around the bench mark had been in cultivation for the last 10 years of the period and for some time previously, while 28 percent of the land along the subsidence line had never been cultivated and the remainder had been cropped for only a few years. This comparison would again indicate that cultivation could account for only a small portion of the total subsidence. However it is possible that the burning along the subsidence line may have about equaled the loss due to cultivation around the bench mark. The available data for the old subsidence lines and those for the Everglades Experiment Station lines indicate that cultivation does not account for any considerable portion of the total subsidence.

Effect of Wind Erosion

Wind erosion does not appear to be an important factor in causing soil loss. During most of the period from early fall until late spring the fields are protected by crops and after the crops are off weeds soon cover the ground. Where the water table is within 2 feet of the surface the moisture also aids in preventing wind losses.

The subsidence shown for the Everglades Experiment Station lines, indicate that the above statement is correct. If wind erosion has been large, lines "G" and "H" should have shown a substantially greater loss in elevation than the "East Line." When the top soil is very dry and pulverized by cultivation, a strong wind may cause considerable loss, but in general it does not seem probable that wind erosion on the areas discussed in this report causes a substantial loss of soil.

Summary and Conclusions

In the Everglades area, the available data show the greatest depths of peat soil to be near Lake Okeechobee, and a gradual decrease in this depth as the edge of the Glades is approached. Some records along the east side of the lake show depths of 12 to 14 feet. Most of the muck and peat soil now in cultivation around Lake Okeechobee is in pumping units in which the major subsidence has already taken place.

In the heavier muck soils, such as the "custard apple" belt adjacent to Lake Okeechobee, the subsidence appears to be less than that in the sawgrass peat farther out from the lake. This is due to the higher mineral content and greater density of the custard apple soil.

Subsidence appears to be proportional to the depth of deposit above the permanent water table, or to the total depth where the water table is below the bottom of the deposit as in the Davie area. The subsidence curves for the Okeelanta line and line S near Fellsmere indicate that the amount is dependent on the depth to the water table rather than upon the total depth of soil (see figs. 2 and 4).

Following drainage, the rate of subsidence decreases with time, as shown by figures 2 and 4. The curve of subsidence apparently approaches a tangent parallel to the time axis, and it seems probable that if fires are prevented, the rate of subsidence will be reduced to a very small amount. The small loss due to slow oxidation may be largely offset by the addition of the fibrous portion of plant roots. As subsidence continues, the density of soil above the water table apparently increases.

The available data appear to show that cultivation does not account for any considerable portion of the total subsidence. A study of the three lines at the Everglades Experiment Station, where the data were most reliable, indicates only a small effect due to cultivation. However, the effect of cultivation should be given further study under controlled conditions.

Much damage to peat soils has been done by fires. In areas where the depth of the water table is maintained at an optimum level by control works or pumping units thus preventing cracks in the soil, serious fires seldom occur. In such areas the surface litter may be burned with little or no damage to the soil due to moisture content preventing burning, but levees, situated well above the level of the water table and often being in an extremely dry condition, are sometimes destroyed. The greatest fire damage occurs outside of pumping units where the uncontrolled water table frequently

drops to such low levels as to allow excessive moisture losses and soil cracking. These cracks greatly increase the rate and amount of evaporation, hence the soil is much dryer than otherwise. The fires readily work down into the cracks and become very difficult to control.

The available data for deep peat deposits indicate total losses in elevation of 4 to 5 feet in the first 20 years following original drainage, and it seems probable that an additional loss of as much as 1 foot may occur in the next 10 years. However, if adequate drainage had been maintained in the deep peat areas by deepening the drainage systems, the rate and amount of subsidence would probably have been greatly increased over actual figures obtained. If the depth of soil underlain with rock becomes less than 2.5 to 3 feet, successful cultivation will be difficult on account of the limitation in depth of farm ditches.

Before new lands are brought into use, the depths of peat should be determined and the probable subsidence over a period of years estimated from the known rate of subsidence in similar areas. The cost of reclamation can then be compared with the probable returns from the lands during the estimated period of usefulness, and a decision reached as to whether the cost is justified. In the design of ditches and pumping plants the probable subsidence should be given careful consideration.